AD-758 263

# CODING SYSTEMS IN PERCEPTION AND COGNITION

Ray Hyman

Oregon University

Prepared for :

Air Force Office of Scientific Research
Advanced Research Projects Agency

1 December 1972

# CODING SYSTEMS IN PERCEPTION AND COGNITION

## A Final Technical Report on a Five-Year Project*

Principle Investigator: Ray Hyman

Co-Investigators:

Barry Anderson (8/3/67 to 8/31/68)
Fred Attneave
Jacob Beck (9/1/70 to 8/31/71)
Richard W. Haller
Douglas L. Hintzman (6/15/69 to 8/31/72)
Steven W. Keele
Michael I. Posner
Gerald M. Reicher
Benson Schaeffer
Wayne A. Wickelgren (8/1/69 to 8/31/71)

Visiting Scholars:

Henry K. Beller
Joe L. Lewis
Jeanette Silveira
Carlo Umilta



Period of Project: 1 August 1967 through 31 August 1972

Amount of Money: $1,446,203



December 1, 1972

*Actually, this report covers two contracts: Contract F44620-67-C-0099 (from 8/1/67 through 8/31/71) and Contract F 44620-71-C-0126 (from 9/1/71 through 8/31/72). The final report for the first contract was submitted at the end of the four year contract period. Technically, this final report deals with the second contract. However, we have found it feasible to report the accomplishments for the entire five-year period of both contracts at certain places in this report. A common bibliography and key word list, for example, is provided to cover the entire period covered by both contracts.

UNCLASSIFIED

Security Classification

# DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

| | |
|---|---|
| 1. ORIGINATING ACTIVITY (Corporate author) University of Oregon, Department of Psychology, Eugene, Oregon 97403 | 2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED |
| | 2b. GROUP |

3. REPORT TITLE

CODING SYSTEMS IN PERCEPTION AND COGNITION

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Scientific Final

5. AUTHOR(S) (First name, middle initial, last name)

Ray Hyman

| | | |
|---|---|---|
| 6. REPORT DATE 1 December 1972 | 7a. TOTAL NO. OF PAGES ~~76~~ 77 | 7b. NO. OF REFS 135 plus 56 talks |
| 8a. CONTRACT OR GRANT NO. F44620-71-C-0126 | 9a. ORIGINATOR'S REPORT NUMBER(S) | |
| b. PROJECT NO. AO 966 | | |
| c. 61101D | 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) AFOSR - TR - 73 - 0530 | |
| d. 681313 | | |

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

| | |
|---|---|
| 11. SUPPLEMENTARY NOTES TECH, OTHER | 12. SPONSORING MILITARY ACTIVITY Air Force Office of Scientific Research, 1400 Wilson Boulevard, Arlington, Virginia 22209 (NL) |

13. ABSTRACT

The variety of experiments completed under the contract successfully isolated ways that humans encode and employ information to meet task demands. The results indicate that, when a stimulus is presented, two or more separate coding processes proceed in parallel. One process may build up an iconic representation of the stimulus object; another process is the retrieval of one or more name codes for the stimulus pattern. For some tasks the response depends completely on the iconic code; for others it depends on the name code. Not only do humans typically convert iconic codes into name codes (abstraction), but, when the occassion is appropriate, they can reverse the process and generate iconic representations from name codes. The build up or construction of the iconic representations appears to take place in a three-dimensional analog medium. The particular representation that is achieved is dependent upon a hill-climbling procedure that is guided by the minimum principle. The build up of information apparently proceeds independently of the individual's state of alertness. Alertness affects the speed of response by changing the subject's criterion for responding. Under high alterness he is willing to respond with less information. Speed of responding can also be affected by selectivity. Selectivity operates on particular aspects of a stimulus enabling the subject to begin constructing some aspects of the representation prior to actually receiving the stimulus (expectancy). Alertness increases speed at the expense of errors; selectivity increases speed without increasing errors. Work also progressed on the third component of attention--conscious processing.

DD FORM 1 NOV 65 1473



UNCLASSIFIED

| 14. KEY WORDS | LINK A | | LINK B | | LINK C | |
|---|---|---|---|---|---|---|
| | ROLE | WT | ROLE | WT | ROLE | WT |
| Coding Systems | | | | | | |
| Perception | | | | | | |
| Cognition | | | | | | |

Form Approved
Budget Bureau No. 22-R0293



FINAL TECHNICAL REPORT*

CODING SYSTEMS IN PERCEPTION AND COGNITION

ARPA Order 966
Program Code 1D20
Under Contract to: The State of Oregon acting by and through the Oregon State Board of Higher Education on behalf of the University of Oregon

Effective Date: 1 September 1971
Contract Expiration Date: 31 August 1972
Amount of Contract Dollars: $154,872
Contract Number: F44620-71-C-0126

Principal Investigator: Ray Hyman
Professor of Psychology
(503) 686-4910 or 686-4962

Title: Coding Systems in Perception and Cognition

Sponsored by: Advanced Research Projects Agency
ARPA Order No. 966

*This contract is a continuation of Contract F44620-67-C-0099 of same title. The key facts of that contract:
ARPA Order: 966
Program Code: 0D20
Under Contract to: same as above
Effective Date: 1 August 1967
Expiration Date: 31 August 1971
Amount of Contract Dollars: $1,291,331
Principle Investigator: same as above
Sponsor: same as above

# TABLE OF CONTENTS

## 2.0. Technical Report Summary

The purpose of the project on Coding Systems in Perception and Cognition was to bring together and focus upon a common theme the skills of experimental psychologists in perception, psychophysics, memory, attention, and human performance. The common theme was the way humans represent or code information in order to accomplish a variety of tasks. When the project was initially proposed in 1966, the experimental work on human performance was already making it clear that humans code information in a variety of different formats--visual, auditory, articulatory, kinesthetic, symbolic or verbal. Moreover, these different codes seemed to differ in a variety of ways that could be important for various task demands. We wanted to investigate such questions as which codes were most effective for various tasks and situations; to what extent is the employment of one code rather than another optional; how do the codes interact with one another in various tasks; what is gained and what is lost in converting from one code to another; etc.

More specific objectives were spelled out in our contract as follows:

"1. Conduct research on the interaction between coding systems and stimulus events in perceptual and cognitive tasks in human subjects.

"2. Conduct experiments on perceived tridimensionality, spatial coding, similarity grouping, and pitch as a medium in which patterns occur.

"3. Construct and test a general model of human pattern recognition.

"4. Conduct research on immediate recall, semantic memory, and the effects of similarity and repetition on memory.

"5. Conduct research on human performance, including experimental studies of attention, memory storage, memory retrieval, movement control, motor skills, and pattern recognition."

Just about all of the experiments in the project deal with the first objective in one way or another. Posner's work on abstraction and generation is an especially good example of how we tackled this objective. In dealing with a stimulus pattern our results suggest that two or more coding processes may proceed in parallel. One process, for example, is a build up or construction of an iconic representation of the stimulus; another is the contact or retrieval of one or more "name" codes for the stimulus pattern. Posner and his colleagues have learned a great deal about how these codes function by devising techniques which enable us to separately manipulate or affect these different codes. For some tasks the subject depends completely upon the iconic code; for other tasks he needs to employ the name code. When our project began, it was assumed by many investigators that processing inevitably went from an iconic code to a name code. The results from our studies indicate that the process can go in the reverse way (generation) as well.

The second objective has been the focus of all of Attneave's work on this project, as well as some of the work of Beck. Attneave's experiments on tridimensionality have lead to a model of how humans represent perceptual information at the preprocessing stage. The evidence strongly suggests that this representation is analog (rather than digital) in nature. Of the infinite number of representations of a stimulus pattern that can be constructed, the human perceiver seems to achieve that representation that minimizes a "description" of the pattern within a three-

dimensional, Euclidean framework. As a general principle, the minimization principle has little predictive value because it is not always obvious what the system is minimizing and with respect to what criteria it guides such minimizing. But Attneave has made considerable progress in defining what will be minimized within specific task situations. The findings seem to have surprising generality, including not only tasks involving directly perceiving tri-dimensionality in projective drawings, but in tasks involving ambiguous figures, and similarity grouping.

The third objective of testing a general model of human pattern recognition has been tackled by Hyman and his colleagues, building upon the previous and concurrent work of Attneave, Posner and Keele. The original model, postulating three successive and overlapping stages in pattern mastery has not fared well in the face of data resulting from a series of experiments. The work is continuing with the attempt to fit a new model to the data. In general, however, the data suggest that subjects employ both an analog and digital coding system simultaneously in learning to classify stimulus patterns into one of two categories. The "digital" component of the system corresponds to what Attneave calls a "schema" and Posner and Keele refer to as a "prototype". The subject seems to abstract from various representatives of the category an idealized or "composite" prototype of that category. Subsequent patterns are then classified or identified in terms of how similar they are to one of these idealized prototypes. The "analog" part of the process refers to the continuum or space within which the subject detects degree of similarity and dissimilarity to prototypes. When the model is more fully worked out,

we hope it will give us a way of reconciling models of coding that are based on continua or analog metaphors and those which are based on discontinuities or digital metaphors.

The fourth objective has been tackled by a variety of experiments in memory by Reicher, Hintzman, Schaeffer and Wickelgren. Hintzman's findings show that subjects store many other aspects of a memory task than just a list of items which vary in strength--they can retrieve information about the frequency, spacing, and modality of such items as well. While such work implicates a variety of more or less separate trace columns in which the various occurrences of the "same" items are stored, Wickelgren's work focusses upon how the repetitions of the "same" item increment some single surrogate or representative for that item. This problem of remembering the unique setting in which an item occurs as opposed to storing that item in a single location comes up in a variety of ways in our work. The so-called logogen model which Keele employs has to deal with this problem and it is intimately related to the iconic and name codes that Posner studies.

The fifth objective, like the first, cuts across almost all the experiments we have conducted. But the work of Posner and Keele is especially pointed towards this objective. Keele's work seems to point to a system in which memory retrieval is automatic and in parallel and in which various bottlenecks in performing a skilled task occur at the level of movement control. At the level of human thinking, Posner has shown how our various experiments on memory codes, memory organization and mental operations can be brought to bear upon how humans solve

problems. The key concept is that of the working memory in which information retrieved from long-term memory is brought into conjunction with information in short-term memory which depends upon immediate stimulation. It is the limited capacity of this working memory that constrains how well the individual will be able to bring his knowledge to bear upon a given problem. The thinker's task is to get just that combination of informational items into working memory that can solve the problem. Very frequently, the thinker has all the information available for the solution, but he fails to solve the problem because he does not manage to assemble the information in such a way that it can be grasped or combined as a unit. Posner, in his forthcoming book, shows how the kinds of experiments we have done in this project can be helpful in pointing the way towards both theory and techniques that will suggest how to help the thinker overcome the constraints of his working memory.

In addition to the many findings that have emerged from our many experiments, the project resulted in the development and perfection of a number of methodological tools for studying coding systems. Fagot's work on separately testing underlying assumptions when using human subjects as measuring instruments, Attneave's method for studying tri-dimensionality, Posner's matching procedures and his new techniques for studying the physiological concomitants of preparation, Schaeffer's and Conrad's methods for assessing semantic structures and Warren's technique for detecting how far abstraction has proceeded are just a few of the many new tools, techniques and paradigms that we have developed. Our most important methodological achievement was the construction and development of an automated

laboratory based upon the two laboratory computers we purchased under this contract (a PDP-9 and a PDP-15). About 70% of the research was controlled by this laboratory. Now that we have finally obtained a permanent place to house this laboratory, we expect that this facility can serve almost all of our experimental psychologists who will continue, under various governmental grants, to build upon the work that was initated under this project.

It is, of course, impossible to summarize all the findings from such a fruitful project that already has produced a bibliography of more than 130 items and will eventually result in anywhere from 160 to 200 published documents. Fortunately, many integrative summaries are or will soon be available of large portions of our work. In addition, the principal investigator hopes to write a later integrative summary of the project when sufficient time has elapsed to allow much of the uncompleted work to be finished and to digest the implications of the work as a totality. Meanwhile, the present final technical report will give a very general overview and point to particular studies that will help provide partial integration of our work. As an aid to the reader, in addition to a regular alphabetized bibliography of our work, we also provide a cross-referenced listing of our work under various key words.

## 3.0. Introduction

Our initial proposal to do research on Coding Systems in Perception and Cognition described our intentions in the following words:

"The proposal deals with the interaction between coding systems and stimulus events in perceptual and cognitive tasks. This interaction is viewed as a reciprocal relation between the form of the coding system and the characteristics of the stimulus event. On the one hand, we want to investigate the ways in which the characteristics of the coding system are determined by the qualities and organization of components of the stimulus event. On the other hand, we want to study how the efficiency with which an individual operates upon the stimulus information is determined by the characteristics of the coding system which he employs in the situation. The general plan is to attack this issue by means of a series of different, but closely coordinated, research projects. The projects will individually investigate the same problem from a variety of different viewpoints--form perceptions, multidimensional psychophysics, scaling, decision and choice theory, concept learning, skill learning, inductive logic, and problem solving. We will coordinate the projects by means of several devices: 1) the formulation and application of a common terminology, notation, and system of concepts; 2) the use of identical stimulus sets; 3) the use of common tasks, dependent variables, equipment, and experimental designs; 4) the rotation of research assistants among projects; and 5) a single individual as principal investigator who has the authority to decide,

at each choice point, whether a given experiment does or does not directly contribute to the overall goal of helping us understand how the characteristics of a coding system affect an individual's ability to use information in perceptual and cognitive tasks."

Those intentions were written approximately seven years before this present report. The Final Technical Report on Contract F44620-67-C-0099 summarized what we did during the first four years of our project to fulfill these intentions. The present Final Technical Report (on Contract F44620-71-C-0126) attempts to convey what we accomplished over the five-year period spanned by both contracts on Coding Systems in Perception and Cognition.

Ideally, this final report would consist of an integrated presentation of our findings about how coding systems operate in human performance. Instead, the report will fall far short of that ideal. One reason is that this report has to be written only a short time interval from the end of the contract. This does not allow time for appropriate digestion and interweaving of the more than 130 written documents that have already been completed on the basis of research supported by the project. Also, many of the experiments supported by the project have not yet been brought to completion. Some are waiting to be written up; others still are in the data-analysis stage; and many projects started under the contract are being continued under other auspices. So the full story is not yet in.

Consequently, this report will suggest the direction of the final integration without actually providing it. Fortunately, some of the monographs already written by some of the investigators or being planned by them provide at least partial integrations of large segments of our

work. Also, the principal investigator hopes to write a fuller and more integrated summary of the overall project at a later date when most of the returns will be in and when sufficient time has occurred. As a step in this direction he will conduct a graduate seminar in the Spring of 1973 whose objective will be to develop an integrated overview of our accomplishments on this project.

Because the bulk of the work on this project originates with the human performance tradition, integrating much of this work within a common framework will not be too difficult. Indeed much of this integration has already been accomplished in Steve Keele's book <u>Attention and Human Performance</u> and Posner's forthcoming book on <u>Memory and Thought</u>. Between them, these two books provide an integrated framework within which to organize the experiments of Reicher, Schaeffer, Posner, Keele, Hintzman and their associates. All of the experiments done by these investigators under this project fit naturally into the human information processing viewpoint.

But this still leaves the work of Attneave, Beck, Fagot, Wickelgren and their associates to be brought into the picture. The work of these latter investigators, although also oriented towards coding systems, originates in different traditions. Attneave and Beck represent the more classical approach to perceptual problems, especially those problems of organization, segregation and patterning that the Gestalt psychologists challenged us with. Attneave pioneered in the application of information theory to Gestalt problems such as that of "good figure". But this aspect of information theory stems from Claude Shannon and emphasizes the

description and quantification of structures or sets of possibilities. But the information processing conceptions used in the human performance area stem more from cybernetics and modern computer programming. This latter viewpoint emphasizes the flow of information from one isolable subsystem to another rather than the specification of the ensemble of possibilities at any one point in the process. Perhaps for this reason the way to integrate Attneave's work with that of Posner and Keele has not yet been resolved to our satisfaction. But the direction that such an integration will take seems discernible. Within our current framework, Attneave and Beck, and to some extent Fagot as well, focus on the dynamics and structure of the coding process that occurs at a single stage, in this case the preprocessing or preselection stage. The major concern is with how the stimulus information is represented _prior_ to contact with memory. The human performance viewpoint tends to take this stage for granted because it is interested not in specifying what goes on at a particular stage, but rather in describing the flow of information between stages. In other words, it is more concerned with the interfaces between components of the system rather than in the components themselves.

Fagot's work on the psychophysical law is even more difficult to fit into the total picture. In this case, the problem might be that the task given to subjects in these sorts of studies is rather an unnatural one. The subject is asked to make focal what is ordinarily part of the background. But what is relevant to the other research projects is the methodological achievements of Fagot and his associates in showing us how to employ subjects as calibrators of their own phenomenal experience. Independent of the substantive contribution, this work on the psychophysical law has

produced tools and techniques for knowing when subjects are estimating magnitudes according to some meaningful measurement process. The work has also resulted in interactive computer procedures for fitting a variety of functions to data. Both these latter contributions have already proved valuable in enabling investigators such as Hyman to use subjective data in rigorous fashion and to fit complicated models to the output.

Wickelgren's work stems from still another tradition that is not easy to integrate with human information processing. That is the classical associationistic tradition with its emphasis upon strength and decay of associational traces. Again, without claiming to have achieved a satisfactory resolution, we can see glimmerings of how this integration with the other work may take place. Keele and Posner, among others, have been making increasing use of Morton's Logogen concept to describe certain aspects of the coding of information in their experiments. This logogen concept, in turn, behaves very much like a concept in the associationistic theories of Wickelgren in that inputs referring to the same concept, regardless of specific differences in modality and form, add increments of strength to that concept.

In the following parts of the report we will briefly indicate some of the major themes or focii around which the final integration will be made. We begin with Attneave's work on tri-dimensionality and minimum principle. This work in itself can serve as the basis for integrating the contributions of Beck, Hyman, and Fagot to some extent. It focusses on coding and perceptual dynamics that are preprocess in the sense that contact with memory is not necessarily involved. The next section deals

with Keele's work, especially with his book on Attention and Human Performance. This book integrates much of the work done by Reicher, Hintzman, Posner, Keele and their associates. Keele's book overlaps with, as well as complements, Posner's forthcoming book on Memory and Thought. Posner's work is the topic of the next section. In a very real sense, Posner and his associates provide the cement that binds the whole project together. The emerging theory from Posner's work comes closest to including all of the experimental research conducted under this project. Indeed, this principal investigator believes that if he can comfortably mesh the work of Attneave with that of Posner, he will have solved the problem of how to completely integrate all of the project. Posner's work is followed by a brief account of the still unfinished work of Hyman and his associates on pattern recognition. This work and its emerging theoretical formulation is seen as one way in which the bridge between Attneave and Posner might be built. Finally, in our overview of experimental results there is a brief section on the contributions by the remaining investigators and some suggestions as to how their work will fit into the ultimate unified picture.

We then say a few words about our automated laboratory and about the number and variety of people who have contributed to this project. This is followed by a few words on the ramifications and implications of our work.

Jacelyn Weddell, under the supervision of the principal investigator, prepared the key word section under which the various articles are cross-referenced.

## 4.0. Accomplishments

During the five years of the project we accomplished many things. We had special classes and colloquia; we constructed the automated laboratory and developed it into a unique and effective facility; we produced many MA theses and Ph.D. dissertations; we gave talks at conventions, meetings and universities all over this country and abroad; we brought in visitors as visiting scholars, speakers, or consultants; we produced many publications and more are on the way; and we completed many experiments with a variety of results. In this section the accomplishments we speak about will be those related to the results of our experimental research.

## 4.1. Analog Systems and Preprocessing: the work of Attneave

The work of Attneave on this project has been particularly satisfying because it has lead to an unexpected integration of a wide range of perceptual phenomena--ambiguous figures, figure-ground, depth perception; "pragnanz", etc. A good start at getting the flavor of this integration is Attneave's Scientific American article on multistability in perception (1971). A more systematic summary of his work and his emerging ideas about the minimum principle and its operation in perception is his chapter on "Representation of Physical Space" (Attneave, 1972). The article on "Triangles as ambiguous figures" (Attneave, 1968) provides an excellent illustration of the power of Attneave's ideas about an internal Cartesian coordinate system in dealing with a rather challenging perceptual phenomenon.

The coding system that Attneave has been studying is one that operates at the preprocessing level. Even before it contacts memory, the stimulus

input is coded and organized in a rather sophisticated way. Of all the ways in which the same stimulus input can be repre ted, that way which minimizes complexity with respect to a hypothetical internal reference system is selected. This internal reference system, as revealed by Attneave's experiments, appears to be a three dimensional, Euclidean coordinate system with preferred axes corresponding to phenomenal vertical, horizontal and front-back. It is a continuous analog medium within which simplifications, according to a principle of perceptual economics, are made even before contact is made with memory. Once memory is contacted, of course, further revisions and interpretations can be carried out on the stimulus material. But Attneave's work emphasizes what the Gestalt psychologists also wanted to emphasize; much of the important operations upon stimulus input occur prior to the operation of "experience" in terms of past associations.

What is pleasantly surprising about this analog coding system is its universality. It seems to be importantly implicated not only in almost all those tasks that are classically referred to as "perceptual", but also in many other tasks that are considered to be cognitive and require problem solving.

4.2. Attention and Human Performance: the work of Keele

Keele's book on Attention and Human Performance (1973) presents a framework and theory around which much of the work of this project can be organized. Keele organizes the book around the processing tasks of storage, retrieval and movement. A central feature of this book is the

theory of attention that Keele develops on the basis of his own work and much of the work conducted on this project. Both the storage of information and the operations made upon information require attention according to Keele's theory. But the retrieval of information from memory does not require attention. Among the advantages of such a system is that the selective mechanism of attention operates on information that is activated in memory rather than on sensory information itself. Sensory information that is meaningless, for example, will not contact information from memory and thus, will not furnish the selective system with anything to operate upon.

Keele's theory relies upon Morton's logogen model. In this case the logogens, corresponding to concepts, are what are activated by sensory inputs. Those logogens which receive sufficient input above a preset threshold are activated sufficiently to be retrieved in memory. Sensory input goes to a set of logogens in parallel. The bottleneck in performance of a given task does not come about because of the number of logogens which happen to be activated. Rather, it occurs as a result of the operations which are subsequently performed upon those logogens which have been activated. Operations require attention; only one operation can be applied at a time.

Keele applies his theory to a wide variety of phenomena ranging from the Von Restorff effect through semantic memory to social applications such as noise control. The book provides not only a coherent view of Keele's own contributions to our project, but it also encompasses about a third of the research conducted under this project.

### 4.3. The Interfacing of Systems: the work of Posner

Posner's work and emerging theoretical framework has been central to this project. The many ways in which Posner's ideas, paradigms, methods and techniques have provided links to all the other investigatorsand students on our project were detailed in the Final Technical Report for the first four years. Even more so than Keele's book, Posner's forthcoming book on "Memory and Thought" provides a framework within which one can organize much, if not all, of the various experiments on the project. While Keele's book organized the material on human performance in its strict and narrower sense, Posner applies the same sorts of principles to the more complex and broader area of human thought and cognition. As a result he casts a broader net. To Keele's coverage, Posner adds the work of additional investigators such as Attneave, Schaeffer, Beller and their associates. Together, Keele's and Posner's books provide a framework for integrating just about all the work on the project with the possible exception of Fagot's work and some of Beck's and Attneave's work.

In 1964, Holt wrote an article "Imagery: The return of the ostracized." (American Psychologist, 1964). The return of the "ostracized" could equally be applied to the concept of "consciousness". Much of Posner's efforts during the five-year project have contributed to the return of "consciousness" as a viable topic for experimental psychology. What was once banished for being so elusive has now gained respectability because of the new "mental chronometry" which enables us to operationally specify when a mental operation does or does not involve conscious processing. Posner and Keele in

their paper on "Time and space as measures of mental operations" (1970) make an important distinction for the problem of measuring mental operations. Operations may require both time and "space". An operation requires "space" if it interferes with the performance of other voluntary activities. Whether an operation requires space can be measured by occupying the central processor with a task that is known to require conscious attention. If the operation being studied interferes with the execution of the standard task (or, alternatively, is interfered with), then it can be said to require conscious attention.

One of the most important paradigms for measuring and isolating mental operations is the form of mental chronometry introduced by Posner and Mitchell (1967). This paradigm requires subjects to match given stimulus pairs as "same" or "different" according to specified criteria such as physical or name identity. This paradigm was developed and elaborated as one of the major tools, not only for Posner and his associates, but also for the other investigators on the project (such as Schaeffer on semantic memory). It was with this paradigm, for example, that Posner and his associates demonstrated that physical and name codes for the same stimulus were isolable subsystems and gave rise to codes with different properties. Moreover, they further demonstrated that the matching of physical forms and the abstracting of the names for these same forms were mental operations that were performed in parallel.

Posner has provided us several integrative summaries of his work over the course of the project. An early and important integration appeared in his chapter on "Abstraction and the process of recognition" (1970).

Here the work resulting from the matching paradigm was tied to his work with Keele on the genesis and retention of abstract ideas. This bridge to pattern recognition also served as a bridge to some of Attneave's work and that of Hyman and his associates on pattern learning. Other important integrative papers are "Coordination of internal codes" (1972), "Attention demands of movements" (with Keele, 1969), "Skill learning" (with Keele, in press), "On the functions of consciousness" (with Klein, 1972), "Traces, concepts, and conscious constructions" (with Warren, 1972), "Components of attention" (with Boise, 1971), and "On the selection of signals" (with Klein, Summers and Buggie, 1973).

The framework provided by the forthcoming book on Memory and Thought divides the study of cognition into two categories: statics and dynamics. The statics of cognition deals with how information is represented in memory. Memory systems differ in their characteristics and in the codes they employ. The two major characteristics are long-term memory and activated memory. Activated memory consists of both short-term memory (immediate memory of stimulus input or sensory analysis) and operational memory (items retrieved from long-term memory). It is activated memory that provides the key to thinking. It is in activated memory, with its limited capacity, that the right combination of information for solutions to problems will or will not occur.

The memory codes are iconic, enactive, and symbolic. These codes usually develop in parallel and which is most salient depends upon a variety of contextual, strategic, and other factors.

The dynamics of cognition deal with the mental operations which are performed on these codes. Operations require time and they may also

require space. When they require space, of course, they involve consciousness. The effectiveness of the problem solver may depend on such things as which operations he can automate (so as to bypass consciousness) and on developing effective ways to retrieve information from long-term storage in such a way that just that combination required will occur together in activated memory.

Posner's most recent work studies the components of attention from both the behavioral and the physiological perspective. Using both his matching paradigm and his newer techniques which measure the evoked potential, Posner has demonstrated how alertness and selectivity, while both enhancing speed of reaction, are separate and independent processes. Alertness, for example, affects the speed of reaction to both same and different reactions alike; selectivity affects the reaction to only one of these components (usually "same"). Selectivity reduces errors as well as facilitating speed of response to the primed target; alertness increases speed of reaction in general without reducing errors and may increase errors. This work suggests an organism that constructs models of the input (expectation) to which it reacts with efficiency and minimal capacity. When the input does not match the internal model, however, an orientation reaction occurs and organism devotes its limited capacity and conscious attention to the discrepancy.

Here we have another potential bridge between Attneave and Posner. In Attneave's earlier work, he developed the notion of perceptual economics. The perceiver was attuned to strip redundancy from the input so as to attend to or cope with points of maximum information (deviation from expectancy). This was a schema-with-correction notion. It is a notion which

now provides a bridge between Attneave, Reicher and others and Posner.

## 4.4. Analog and digital: The work of Hyman

One attribute on which coding systems seem to differ is that of analog versus digital. In the perceptual area, such as the psychophysical models of Fagot and the spatial model of Attneave, the system into which stimulus input is coded or represented is characterized as a continuous medium or space. Even the language and the mathematics is that of continua and analysis. In the cognitive area, on the other hand, the system into which the stimulus input is coded is more often characterized as a discrete set of categories or nodes. The language and mathematics, when applied, is usually that of set theory, the algebra of classes and graph theory. We all agree that both continuous and discontinuous systems characterize human perception and cognition. The problem has been how to coordinate this knowledge into one model or theory. At the moment, most formal models seem to be exclusively analog or digital in nature.

In our project when we talk about "abstraction" and "generation" or when we talk about the "coordination of internal codes" we explicitly or implicitly refer to analog-to-digital and digital-to-analog transformations. One possible link between analog and digital codes is that analog codes seem to characterize more naturally that form of information processing that is done outside the central processor. Preprocessing of stimulus information seems heavily analog in nature; execution of motor programs below the level of conscious control or awareness also seems analog in nature. Some versions of the logogen model and statistical decision theory may suggest clues as to how the analog-digital interaction can be handled.

The logogen model implies an analog-to-digital conversion in that stimulus input to a logogen adds up continuously until a certain threshold point and then the logogen is set off in a discrete manner. Statistical decision making also implies the imposing of a discontinuity upon a continuous space or dimension.

Hyman and his associates began a series of experiments on pattern classification with this analog-to-digital relation in mind. We deliberately set out, in these experiments, to provide a bridge between the work and theories of Attneave and those of Posner. The experiments and concepts were based upon the earlier work of Attneave on "schema-with-correction" and the more recent work of Posner and Keele on the genesis and retention of abstract ideas. The stimulus patterns and the experimental paradigm was taken directly from the Posner and Keele studies. The stimulus patterns were dot patterns. Subjects are shown examples of these patterns and learn to classify them into two categories. Once they can correctly classify the exemplars into the appropriate categories they are then tested on a wide variety of patterns, many of them new, to see how they will classify patterns not previously encountered. Our experiments differed from those of Posner and Keele in two ways. We used only two categories. And, more importantly, our patterns did not differ from each other in random ways, but rather in systematic ways along two dimensions--height and width.

Our patterns could be seen as being drawn from the same continuous Euclidean space with dimensions of height and width. In fact, our multidimensional scaling of similarity judgments made by a panel of judges,

confirmed our belief that subjects would respond to these patterns as if they were drawn from a continuum of patterns that vary in two dimensions that correspond to the physical dimensions of height and width. Our requirement that subjects learn to classify patterns within this space as belonging either to one or another of two categories in effect requires the subject to impose a digital code upon an analog system.

We were concerned with three possible models of how subjects could accomplish this task. One model, the Exemplar Model, says the subject stores a unique description of each exemplar along with the associative bond corresponding to name of the category to which it belongs. In this model, the subject recognizes a new pattern by comparing it, either serially or in parallel, with all of the stored exemplars. If, on the average, the test pattern is closer to the exemplars representing category A, he classifies it as an A; otherwise as a B.

The second model, the Prototype Model, is based on the findings of Posner and Keele, This model says that, during learning or later, the subject will construct a composite figure or surrogate pattern (the prototype) based upon the central tendency of all exemplars for that category. In this case, when presented with a test pattern, the subject need retrieve and compare it to the surrogate of each category. Such a strategy could achieve considerable economy, especially if there were many exemplars and if comparisons were done serially.

The third model, the Rule Model, sees the subject abstracting a rule for classifying the patterns based upon the dimensions on which they vary. He might learn during acquisition or the test phase that all exemplars of A are taller than they are wide. In this case, he need not retrieve either

stored exemplars or prototypes when confronted with a test pattern. Instead, he need only determine if the pattern is taller than it is wide; if yes, then he classifies it as an A; if no, he classifies it as a B.

Our original expectations were that subjects, in fact, use strategies consistent with all three models, but each model is more appropriate at different stages of mastering the pattern task. At the earliest stage of learning, especially when first presented with an exemplar, we felt that the subject would have to rely on a process implied by the Exemplar Model. At a somewhat later stage, especially when there were several exemplars, we felt that the Prototype Model would become appropriate. And, finally, especially during the testing phase in which a large variety of patterns would emphasize the dimensions of variation, the Rule Model might become dominant.

As can be expected, the Exemplar Model and the Prototype Model are quite difficult to distinguish. Our results suggest that subjects perform according to one or the other of these models, but no transitions within a subject take place. More clearly, our subjects rarely, if ever, perform according to the Rule Model. This was so even when we told the subjects the rule in advance.

We are currently reanalyzing the data according to a model more in line with statistical decision theory and Thurstonian models of classification. It is clear from both our scaling and pattern recognition data that subjects perceived our patterns as differing from one another along a single dimension within a Euclidean space. The "A's" tend to be skinny (taller than wide) and the "B's" tend to be squat (broader than tall).

A qualitative picture of their behavior would be something like this. A test pattern is located on this dimension. If it is near the border

between category A and category B, the subject will be inconsistent in how he classifies the pattern and he will take a long time to classify it. If the test pattern is not near the border, he will consistently classify as an A or a B depending upon its direction from the border. His speed of classification, however will depend upon how far the test pattern is from the border. If it is moderately far from the border, he will be reasonably fast and accurate. But if it is very far from the border, his speed of classification will begin to slow down again. It is this last fact that makes the Rule Model inapplicable.

What is suggested is a model of this sort. The subject codes the test pattern simultaneously in two ways. He codes it in terms of where it is located on a continuum (analog coding) and he codes it in terms of how close it is to an idealized member of a given class (the prototype). The prototype is a digital code in the sense that it is a discrete region of the space. The classification is digital as well, since it represents a partition of this space.

This work will probably be completed within the next six months.

4.5. Other Inputs: Fagot, Beck, Haller, Hintzman, Peicher, Schaeffer, Wickelgren.

The Final Technical Report for the first four years adequately covers the contributions of the remaining investigators as well as the visiting scholars. These investigators used whatever time they devoted to the present project during its fifth year to finish and write up work already reported in the preceding report. Some new work was initiated by Dr. Jeannette Silveira as followup on her dissertation on incubation in

problem solving. She confirmed some of the results of that dissertation, but failed to come up with any new findings in a series of experiments to see how different methods of instruction would facilitate later problem solving.

Reicher and Hyman initiated some preliminary experiments on reading and comprehension. These provided the basis for a new research proposal to apply findings from the present project to the study of how subjects comprehend instructional materials. Charles Snyder completed his doctoral dissertation on individual differences in imagery. Snyder conducted four experiments in which he related the vividness and controllability aspects of imagery ability to performance in a variety of tasks, including sketching, problem solving, spatial relations, same-different matching, and detection, naming and classification of letters. Controllability of imagery was significantly correlated with sketch quality, problem solution time, scores on a test of space relations, several aspects of letter detection, same-different matching times, and rate of 'mental rotation' in matching and classification tasks. Vividness of imagery was related to sketch quality and to reproduction measures in general.

Carol Conrad also completed her doctoral dissertation during the fifth year. She used the procedure that Warren developed during his dissertation to determine if abstraction continues beyond the point necessary to perform certain tasks. In Conrad's case, she wanted to see if, when words are interpreted in the context of a sentence, the alternative meanings not implied by the context are also looked up. She was able to demonstrate that, in fact, there does seem to be a separate lexical lookup

stage that precedes the disambiguation of a word when it occurs in a sentence. For example, when subjects are confronted with the sentence, "The sailors sailed into the port", they apparently retrieve the meaning of port that refers to "wine" as well as that which refers to the appropriate meaning of "harbor".

## 5.0. The Automated Laboratory

A full description of the development and current status of our Automated Laboratory was provided in the Final Technical Report for the first four years. In that description we mentioned plans for developing a higher level language called Experiment Writer. Since then, we have perfected and implemented this language so that it is now being used on a routine basis. Graduate students and experimenters who have never learned Fortran or computer programming can now be taught within a matter of hours how to use our Automated Laboratory to set up and run a variety of experiments.

We also have finally cleared all hurdles for renovating the basement of Straub Hall to serve as the new site for the Automated Laboratory. By moving into this new location, we overcome the few remaining hurdles towards making the laboratory a facility that can be used simultaneously and effectively by all the experimental psychologists who have governmental contracts.

## 6.0. Extensions and Ramifications

The major focus of the five-year project on Coding Systems in Perception and Cognition was on gaining maximal generality of our findings across all the areas of experimental psychology from sensory psychophysics through semantic memory. For the most part, we used stimulus inputs

that were relatively meaningless and confronted our subjects with tasks that required them to focus upon the "medium" rather than the "message". Not only were our stimulus inputs semantically meaningless, they were emotionally neutral as well.

Such constraints were deliberate. They served the purpose of enabling us to isolate subsystems of human processing that cut across a wide variety of tasks. And they provided us with a basis for what we hope is an integrated picture of the human as a general processor of information.

But, by the same token, these constraints limit our generalizability in the sense that we have still to demonstrate that the same processes and codes apply when we place the human in naturalistic settings where the information he must cope with is rich in semantic significance and emotional coloring.

Actually, even before the end of this project, some of the work was moving towards more realistic stimulus inputs and real-life tasks. The work of Schaeffer and Conrad on semantic memory is one example. Hyman and Reicher's preliminary experiments on reading and comprehension is another. Still other cases would be Haller and Reicher's study of high skilled performance such as sight-reading in musicians; Schwank's study of the Oregon electoral ballot; and Silveira's dissertation on incubation in problem solving.

Currently, many of the investigators on the project are engaged in, or making plans for, research that will help to extend and apply our findings to social and practical problems. Keele has been working on

ways to employ our findings in coping with environmental problems such as noise, pollution, crowding and over-population. In our renovated facility at Straub Hall, we have included an environmental room which will be used to study the effects of noise and pollution upon human information processing.

We have already mentioned how Posner has extended the range of applicability by applying our findings to the problem of human thinking and problem solving. We have also mentioned the extension to physiological indices as well as our behavioral indices in our study of attention. Posner's work on attention and alertness has provided one way in which emotional and arousal components are naturally entering into what had up to now been the study of "cold cognition". Indeed, because of our interest in bringing emotional aspects of coding into the picture, we have organized a seminar with our social psychological colleagues on "hot cognition". We have also been using emotionally toned words to study the coding and retrieval aspects of the emotional affect as well as the cognitive content of stimuli.

Along with this, Hyman has completed a series of studies on aesthetic preference as another aspect of pattern recognition and retrieval.

The area of semantic memory is being expanded in a major project to apply our findings to a very practical problem--that of comprehending instructional material. Hyman, Reicher, Schaeffer and Wickelgren have joined together to study this problem. We expect help from the other investigators in the project who are also anxious to see how our findings can be extended to the worlds of reading, education, and related matters.

We have seen other possible applications of our work being developed. A doctoral dissertation by Karen Boise used our apparatus and matching procedures to compare brain-damaged patients with normals. The results are promising in enabling us to pinpoint the nature of the deficit in terms of isolable subsystems that we have been studying.

7.0. ARPA Articles Cross Referenced by Key Words (prepared by Jacelyn Weddell).

The following Key Word List is intended only as a guide, not as a complete listing of all relevant terms. Contents of articles, as well as titles, were studied to complete the list. A number of terms which would be common to a great number of articles in the bibliography have been deleted. Most efficient use of the list can be accomplished by noting the articles under a number of related terms and referring to those which are listed more than once.

Fagot, Stewart & Kleinknecht, Submitted
Johnson, 1968
Kleinknecht, 1971
Murdoff, 1971

BUFFER

Attneave & Frost, 1969
Beck & Ambler 1972
Posner, 1970(a)
Posner & Boies, 1971
Posner & Klein, 1972
Posner & Warren, 1972

CAPACITY,LIMITED

Posner, 1969(b),1972(b)
Posner, & Boies, 1971
Posner, Lewis & Conrad, 1972
Posner & Warren, 1972
Schaeffer & Wallace, 1970(b)

CAPACITY, PROCESSING

Boies, 1971
Posner & Boies, 1971
Posner, Lewis & Conrad, 1972
Schaeffer & Wallace, 1970(b)

CARTESIAN COORDINATE SYSTEM

Attneave & Frost, 1969
Frost, R. 1971
Olson, 1970(a),1970(b)

CATEGORY

Conrad, 1971,1972(a),1972(b)
Posner, 1970(b)
Warren, 1970,1972
Well, 1969,1971

CATEGORY FORMATION

Posner, 1969(a)
Schaeffer & Wallace, 1968,1969

CENTRAL PROCESSOR

Posner & Boies, 1971
Posner & Keele, In press 1972

CHANNELS

Lewis, 1970(a)
Warren, 1968

CHESS MASTERS' CODES

Reicher, Haller & Aitken, Submitted

CHOICE REACTION TIME

Umilta, Frost & Hyman,1972

CLASSIFICATION

Boies, 1971
Well, 1969,1971

CLOSED LOOP

Posner & Keele, In press

CLUSTERING

Frost, N. 1970,1971(a),1971(b)
In press
Hintzman, Block & Inskeep, In press

CODES ACOUSTIC

Posner, 1972(c)
Posner & Taylor, 1969
Reicher, Ligon, & Conrad, 1969

CODES, AUDITORY

Posner, 1970(a), 1972(c)
Posner, Lewis & Conrad, 1972
Warren, 1968

CODES, CHESS MASTERS'

Reicher, Haller & Aitken, Submitted

CODES, COLOR

Beller, 1970(b)
Conrad, 1972(b)
Warren, 1970,1972

CODES, COORDINATION OF

Posner, 1972(c)

CODES, KINESTHETIC

Keele, 1968
Posner, 1972(c)
Posner & Keele, 1969, In press

CODES, MULTIPLE

Conrad, 1972(b)
Posner, 1972(c)
Posner & Taylor, 1969
Warren, 1970, 1972

CODES, NAME

Beller, 1970(b),1971
Boies, 1969,1971
Buggie, 1970
Frost, N. 1970,1971(a),1971(b)
In press
Posner, 1970(a),1970(b)
Posner & Boies, 1971
Posner, Boies, Eichelman,
& Taylor, 1969
Posner, Lewis & Conrad, 1972
Posner & Taylor, 1969
Posner & Warren, 1972
Snyder, 1972(b)
Turnbull, 1971
Warren, 1970,1972

CODES, PARTIAL

Beller, 1971

CODES, PERCEPTUAL

Attneave & Frost, 1969
Hintzman,Block & Inskeep, In press
Johnson, 1968

CODES, PHONETIC

Wickelgren, In press (b)

CODES, PHYSICAL

Beller, 1971
Boies, 1969,1971
Posner, 1970(a),1972(c)
Posner,& Boies, 1971
Posner & Taylor, 1969
Posner & Warren, 1972

CODES, RESPONSE

Wallace, 1971

CODES, SEMANTIC

Conrad, 1971,1972(a),1972(b)
Frost, N.,1971(b),In press
Schaeffer & Wallace, 1969,1970

CODES, SHAPE

Attneave & Frost, 1969

CODES, SINGLE vs MULTIPLE

Posner, 1972(c)

CODES, SPATIAL

Attneave, 1969
Attneave & Frost, 1969
Frost, N., 1971(b),In press
Laabs, 1971
Posner & Keele, In press
Posner & Warren, 1972
Snyder, 1972(a)
Wallace, 1970, 1971

CODES, SYMBOLIC

Beller, 1970(b)
Schaeffer & Wallace, 1968

CODES, TRANSLATION OF

Posner, 1972(c)
Posner, Lewis & Conrad, 1972
Rogers, 1972

CODES, VISUAL

Attneave, 1969
Beck & Ambler, 1972
Boies, 1969,1971
Buggie, 1970
Conrad, 1972(b)
Frost, N., 1970,1971(a),1971(b),
In press

JUDGMENTS, INTERVAL

Fagot & Stewart, 1969(b)
Fagot, Stewart & Kleinknecht, Submitted

JUDGMENTS, LIST MEMBERSHIP

Hintzman & Block, Submitted
Hintzman, Block & Summers, Submitted

JUDGMENTS, MAGNITUDE

Fagot, & Stewart 1969(a), 1969(b) 1970(a)
Fagot, Stewart & Kleinknecht. Submitted

JUDGMENTS, PATTERN

Posner, 1970(a)

JUDGMENTS, POSITION

Hintzman, Block & Summers, Submitted

JUDGMENTS, RATIO

Fagot & Stewart, 1969(b)
Fagot, Stewart & Kleinknecht, Submitted
Kleinknecht, 1971

JUDGMENTS, RECENCY

Hintzman & Block, Submitted

JUDGMENTS, SAME-DIFFERENT

Boies, 1969,1971
Eichelman, 1968,1970(a)
Johnson, 1968
Posner, 1970(a),1970(b)
Posner, Lewis & Conrad, 1972
Rogers, 1972
Schaeffer & Wallace, 1968,1970(a), 1970(b)

Taylor, 1968,1969(a),1969(b)

JUDGMENTS, SIMILARITY

Schaeffer & Wallace, 1969

JUDGMENTS, SLANT

Attneave & Frost, 1969

KINESTHETIC CODES

Keele, 1968
Posner, 1972(c)
Posner & Keele, 1969, In press

KINESTHETIC CONTROL

Keele, 1968
Posner, 1969(b)

KINESTHETIC INFORMATION

Attneave, 1969
Keele, 1968
Laabs, 1971
Posner & Keele, In press

KINESTHETIC MEMORY

Keele, 1968
Keele & Ells, In press
Laabs, 1971
Posner & Keele, 1969

LANGUAGE

Conrad, 1972(b)
Posner, 1972(b)
Posner, Lewis & Conrad, 1972

LEARNING, ATTRIBUTE

Schaeffer & Wallace, 1968

PERCEPTUAL UNITS

Johnson, 1968

PFANZALGEL'S MEASUREMENT MODEL

Adams, Fagot & Robinson, 1970
Fagot & Stewart, 1970(b)

PHI-LAW

Fagot & Stewart, 1969(a),1970(a)
Kleinknecht, 1971

PHONETIC CODE

Wickelgren, In press (b)

PHOTOPIC VISION

Fagot & Stewart, 1969(a)

PHYSICAL CODE

Beller, 1971
Boies, 1969,1971
Posner, 1970(a),1972(c)
Posner & Boies, 1971
Posner & Taylor, 1969
Posner & Warren, 1972

PITCH

Attneave & Olson, 1971

POSITION JUDGMENTS

Hintzman, Block & Summers, Submitted

POWER FUNCTION

Fagot & Stewart, 1969(a), 1969(b) 1970(a)
Kleinknecht, 1971

PRACTICE

Boies, 1971
Posner & Keele, In press

PRAGNANZ

Attneave, 1971
Attneave & Frost, 1969

PREPARATION

Posner & Boies, 1971
Posner & Keele, In press
Silveira, 1971

PREPROCESSING

Buggie, 1970
Schaeffer & Wallace, 1968

PRIMACY EFFECT

Hintzman, Block & Summers, Submitted

PRIMING

Beller, 1971
Posner & Klein, 1972
Wickelgren, In press(a)

PROACTIVE INTERFERENCE

Block, 1970,1971
Hintzman & Waters, 1969

PROBLEM SOLVING

Silveira, 1971

PROCESSING, AUTOMATIC

Posner & Warren, 1972

PROCESSING CAPACITY

Boies, 1971
Posner & Boies, 1971
Posner, Lewis & Conrad, 1972
Schaeffer & Wallace, 1970(b)

PROCESSING, HIERARCHICAL

Conrad, 1971,1972(a)
Posner, Lewis & Conrad, 1972
Schaeffer & Wallace, 1969

SHAPE

Attneave & Frost, 1969
Frost, N., 1970,1971(a),1971(b) In press
Frost, R., Submitted
Laabs, 1971
Olson, 1970(a)

SHORT TERM MEMORY (STM)

Beller, 1971
Block, 1970,1971
Highes, 1970
Johnson, 1968
Laabs, 1971
Reicher, Ligon & Conrad, 1969
Stewart, 1969
Taylor, 1968,1969(a)
Warren, 1968
Wickelgren & Berian, 1971
Wickelgren & Norman, 1971

SIGHT READING

Reicher, Haller & Aitken, Submitted

SIGNAL DETECTION

Reicher, Ligon, & Conrad, 1969

SIMILARITY

Beck & Ambler, 1972
Frost, N., 1971(a), In press
Lewis, 1970(a)
Olson, 1970(b)
Posner & Taylor, 1969
Reicher, Ligon & Conrad, 1969
Schaeffer & Wallace, 1968
Wallace, 1970,1971

SIMILARITY JUDGMENTS

Schaeffer & Wallace, 1969

SIMULATION

Posner, 1972(b)

SIZE

Beller, 1970(b)

SKILL LEARNING

Posner & Klein, 1972

SLANT

Attneave & Frost, 1969
Eichelman, 1970(a)
Frost, R., 1971
Laabs, 1971

SLOPE

Attneave & Frost, 1969
Beck & Ambler, 1972
Olson, 1970(b)

SPACE PERCEPTION

Attneave, In press
Attneave & Frost, 1969
Olson, 1970(b)

SPACING, EFFECTS OF

Hintzman & Block, 1970, Submitted

SPATIAL CODING

Attneave, 1969
Attneave & Frost, 1969
Frost, N., 1971(b), In press
Laabs, 1971
Posner & Keele, In press
Posner & Warren, 1972
Snyder, 1972(a)
Wallace, 1970,1971

SPATIAL COMPATIBILITY

Attneave & Frost, 1969
Posner & Keele, In press

SPATIAL OPERATIONS

Buggie, 1970
Frost, R., 1971
Laabs, 1971
Posner, Lewis & Conrad, 1972

SPATIAL REPRESENTATION

Atwood, 1969, 1971
Posner & Keele, In press

Snyder, 1972(a)

SPEECH PRODUCTION

Wickelgren, In press(a)
Wickelgren, In press (b)

SPEECH RECOGNITION

Wickelgren, In press (a)
Wickelgren, In press (b)

STIMULI, DISTAL

Attneave, 1969

STIMULI, PROXIMAL

Attneave, 1969

STIMULI, UNIDIMENSIONAL

Stewart, 1969

STIMULUS, COMPLEXITY

Johnson, 1968

STIMULUS DISCRIMINATION

Ells, 1969

STIMULUS PREPROCESSING

Buggie, 1970
Schaeffer & Wallace, 1968

STIMULUS, RECALLED VS PERCEIVED

Taylor, 1968,1969(a)

STIMULUS RESPONSE COMPATIBILITY

Posner & Keele, 1972
Umilta, Snyder & Snyder, 1972
Wallace, 1970,1971
Well, 1969,1971

STIMULUS RESPONSE COMPETITION

Umilta, Snyder & Snyder, 1972

STRENGTH

Hintzman & Block, 1971
Wickelgren & Berian, 1971
Wickelgren & Norman, 1971

STROOP EFFECT

Conrad, 1972(b)
Hintzman, Carre, et.al., In press
Keele, 1972
Posner & Warren, 1972
Warren, 1970,1972

STRUCTURE, DEEP VS SURFACE

Conrad, 1972(b)

STRUCTURE, SPATIAL VS HIERARCHICAL

Conrad, 1971,1972(a)
Posner & Warren, 1972

SUBJECTIVE LEXICON

Conrad, 1972(b)

SUBJECTIVE PROBABILITY MEASURES

Adams, Submitted

SUBTRACTIVE METHOD

Posner & Taylor, 1969

SUPERORDINATE

Posner, 1970(b)

SUPRAORDINATE

Conrad, 1971,1972(a)

## 8.0 ARPA Bibliography

This bibliography is complete as of December, 1972. Changes are continuously being made in that articles in preparation are being published, submitted articles are accepted, etc. Also, at the time of this writing, many articles are in preparation and some articles may or may not be written depending upon the completion of data analyses and experiments.

The bibliography contains a small proportion of articles that were not directly credited as being sponsored by the present ARPA contracts. Because our investigators sometimes had other contracts or grants which overlapped with the present project, it was sometimes quite arbitrarty how the credit for sponsorship was assigned. It was felt that articles published by investigators which were intimately related to the purposes of the project even though at the time they were assigned to other contracts should be included here for completeness.

ARPA BIBLIOGRAPHY
1968-1972

Adams, E. W. The empirical status of non-necessary axioms in theories of subjective probability. Submitted to J. of Mathematical Psychology.

Adams, E. W., Fagot, R. F., & Robinson, R. E. On the empirical status of axioms in theories of fundamental measurement. J. of Mathematical Psychology, 1970, 7, 397-409.

Attneave, F. Multistability in perception. Scientific American, December, 1971, 63-71.

Attneave, F. The representation of physical space. In A. W. Melton and E. Martin (Eds.), Coding theories in learning and memory. New York: Holt, Rinehart & Winston, 1972.

Attneave, F., & Benson, B. Spatial coding of tactual stimulation. J. of Experimental Psychology, 1969, 81, 216-222.

Attneave, F. & Frost, R. The determination of perceived tridimensional orientation by minimum criteria. Perception and Psychophysics, 1969, 6, 391-396.

Attneave, F., & Olson, R. K. Pitch as a medium: A new approach to psychophysical scaling. American J. of Psychology, 1971, 84, 147-166.

Atwood, G. E. Experimental studies of mnemonic visualization. Ph.D. Dissertation, 1969.

Atwood, G. E. An experimental study of visual imagination and memory. Cognitive Psychology, 1971, 2, 290-299.

Beck, J. & Ambler, B. Discriminability of differences as a function of concentrated and distributed attention. In preparation.

Beck, J., & Ambler, B. Discriminability of differences in line-slope and in line-arrangement as a function of mask delay. Perception & Psychophysics, 1972, 12, 33-38.

Beck, J. & Stevens, A. On the discrimination of temporal order of two lights. In preparation.

Beller, H. K. Parallel and serial stages in matching. J. of Experimental Psychology, 1970(a), 84, 213-219.

Beller, H. K. Priming: Effects of advance information on matching. J. of Experimental Psychology, 1971, 87, 176-182.

Beller, H. K. Problems in visual search. International Yearbook of Cartography, 1972, 12, 137-144.

Block, R. A. The effects of cues to forget in short-term memory tasks. M. A. Thesis, 1970.

Block, R. A. Effects of instructions to forget in short-term memory. J. of Experimental Psychology, 1971, 89, 1-9.

Boies, S. J. Memory codes in a speeded classification task. Ph.D. Dissertation, 1971.

Boies, S. J. Retention of visual information from a single letter. M. A. Thesis, 1969.

Buggie, S. E. Stimulus preprocessing and abstraction in the recognition of disoriented forms. M. A. Thesis, 1970.

Conrad, C. Cognitive economy in semantic memory. J. of Experimental Psychology, 1972(b), 92, 149-154.

Conrad, C. Studies of the subjective lexicon. Ph.D. Dissertation, 1972(a).

Conrad, C. An analysis of a hierarchical model of semantic memory organization. M. A. Thesis, 1971.

Eichelman, W. H. Changes in the relative discriminability of slant and configuration differences. Ph.D. Dissertation, 1970(a).

Eichelman, W. H. Familiarity effects in the simultaneous matching task. J. of Experimental Psychology, 1970(b), 86, 275-282.

Eichelman, W. H. Letters as units of processing in a visual matching task. M. A. Thesis, 1968.

Eichelman, W. H. Stimulus and response repetition's effects for naming letters at two response-stimulus intervals. Perception & Psychophysics, 1970(c), 8, 94-96.

Ells, J. G. Attentional requirements of movement control. Ph.D. Dissertation, 1969.

Fagot, R. F. & Stewart, M. R. Effects of feedback on linear and consistency performance. In preparation.

Fagot, R. F. & Stewart, M. R. An experimental comparison of stimulus and response translated power functions for brightness. Perception & Psychophysics, 1970(a), 3, 297-305.

Fagot, R. F. & Stewart, M. R. Individual half-judgment brightness functions. Perception & Psychophysics, 1969(a), 5, 165-170.

Fagot, R. F. & Stewart, M. R. Tests of product and additive scaling functions. Perception & Psychophysics, 1969(b), 5, 117-123.

Fagot, R. F. & Stewart, M. R. Test of a response bias model of bisection. Perception & Psychophysics, 1970(b), 7, 257-262.

Fagot, R. F., Stewart, M. R. & Kleinknecht, R. Numerical representations and experimental tests of ratio and interval direct scaling methods. Submitted to Perception & Psychophysics.

Frost, N. Clustering in the free recall of pictorial stimuli. M. A. Thesis, 1970.

Frost, N. Clustering by visual shape in the free recall of pictorial stimuli. J. of Experimental Psychology, 1971 (a), 88, 409-413.

Frost, N. Encoding and retrieval in a visual memory task. J. of Experimental Psychology, 1972, 95, 317-326.

Frost, N. Interaction of visual and semantic codes in memory. Ph.D. Dissertation, 1971(b).

Frost, R. Constancy of perceived spatial relationships on a surface viewed at a slant. Ph.D. Dissertation, 1971.

Frost, R. On the convergence of apparently vertical straight lines. Submitted to Perception & Psychophysics.

Hintzman, D. L. Confidence ratings in recall: A reanalysis. Psychological Review, 1972. In press.

Hintzman, D. L. Effects of repetition and exposure duration on memory. J. of Experimental Psychology, 1970, 83, 435-444.

Hintzman, D. L. On testing the independence of associations. Psychological Review, 1972, 79, 261-264.

Hintzman, D. L. & Block, R. A. Memory for the spacing of repetitions. Submitted to J. of Experimental Psychology.

Hintzman, D. L. & Block, R. A. Memory judgments and the effects of spacing. J. of Verbal Learning & Verbal Behavior, 1970, 9, 561-566.

Hintzman, D. L. & Block, R. A. Repetition and memory: Evidence for a multiple-trace hypothesis. J. of Experimental Psychology, 1971, 88, 297-306.

Hintzman, D. L., Block, R. A., & Inskeep, N. R. Memory for mode of input. J. of Verbal Learning & Verbal Behavior, 1972, 11, 741-749.

Hintzman, D. L., Block, R. A. & Summers, J. J. Contextual associations and memory for serial position. Submitted to J. of Experimental Psychology.

Hintzman, D. L., Carre, F. A., Eskridge, V. L., Owens, A. M., Shaff, S. S. & Sparks, M. E. "Stroop" effect Input or output phenomenon? J. of Experimental Psychology, 1972. In press.

Hintzman, D. L. & Waters, R. M. Interlist and retention intervals in list discrimination. Psychonomic Science, 1969, 17, 357-359.

Hintzman, D. L. & Waters, R. M. Recency and frequency as factors in list discrimination. J. of Verbal Learning & Verbal Behavior, 1970, 9, 218-221.

Hughes, M. H. Some grammatical effects in immediate recall of sentences. M. A. Thesis, 1970.

Hyman, R., & Frost, N. Stimulus-generalization and distinctive features in pattern-recognition. In preparation.

Hyman, R., & Umilta, C. The information hypothesis and non-repetitions. Acta Psychologica, 1969, 30, 37-53.

Johnson, W. The effect of stimulus complexity and interstimulus interval on "same" "different" reaction time. Ph.D. Dissertation, 1968.

Keele, S. W. Attention and human performance. Pacific Palisades, California: Goodyear, 1972(a).

Keele, S. W. Attention demands of memory retrieval. J. of Experimental Psychology, 1972, 93, 245-248.

Keele, S. W. The effects of input and output modes on decision time. J. of Experimental Psychology, 1970, 85, 157-164.

Keele, S. W. Movement control in skilled motor performance. Psychological Bulletin, 1968, 70, 387-403.

Keele, S. W. Repetition effect: A memory dependent process. J. of Experimental Psychology, 1969, 80, 243-248.

Keele, W. W. & Boies, S. J. Processing demands of sequential information. Memory and Cognition, 1973, 1, 85-90.

Keele, S. W. & Ells, J. G. Memory characteristics of kinesthetic information. J. of Motor Behavior. In press.

Klein, R. Vision and kinesthesis in movement reproduction. M. A. Thesis, 1972.

Kleinknecht, R. E. Psychophysical functions and a threshold parameter. M. A. Thesis, 1971.

Laabs, G. J. Cue effects in motor short-term memory. Ph.D. Dissertation, 1971.

Laabs, G. J. & Lewis, J. L. The effect of unattended items on recency judgments of shadowed items. In preparation.

Lewis, J. L. Activation of "logogens" in an audio-visual word task. Ph.D. Dissertation, 1970(a).

Lewis, J. L. Activation of "logogens" in an audio-visual word task. In preparation.

Lewis, J. L. Activation of logogens in a bisensory task. J. of Experimental Psychology. In press.

Lewis, J. L. Computer system options for behavioral research. In preparation.

Lewis, J. L. Semantic processing of unattended messages using dichotic listening. J. of Experimental Psychology, 1970(b), 85, 225-230.

Lewis, J. L., Boies, S. J., & Osgood, G. H. Zoroaster: A multiprogramming system for psychological research. Behavior Research Methods and Instrumentation, 1971, 2, 106-107.

Lewis, J. L., Osgood, G. W., & Hebert, J. J. PLEIDES: Real-time sharing on a small computer. In preparation.

Murdoff, K. Rate of change effects for brightness matching task. Unpublished paper, 1971.

Olson, R. K. The role of shape variables in the trapezoidal window illusion. Ph.D. Dissertation, 1970.

Olson, R. K. & Attneave, F. What variables produce similarity groupings? American J. of Psychology, 1970, 83, 1-21.

Posner, M. I. Abstraction and the process of recognition. In G. H. Bower and J. T. Spence (Eds.) Advances in learning and motivation, Vol. III, New York: Academic Press, 1970(a), Pp. 44-100.

Posner, M. I. After the revolution....what? Review of D. E. Broadbent, Decision and stress. Contemporary Psychology, 1972(a), 17, 185-188.

Posner, M. I. Cognition...hardboiled and soft shelled. Review of J. S. Antrobus, Cognition and effect. Contemporary Psychology, 1971(a), 78, 391-408.

Posner, M. I. Cognition: Natural and artificial. In R. Solso (Ed.), Proceedings of the Loyola Conference on Cognition, 1972(b). In press.

Posner, M. I. Coordination of internal codes. In W. G. Chase (Ed.), Proceedings of the Eighth Carnegie Conference on Cognition, 1972(c). In press.

Posner, M. I. Concept indentification...information processing approaches. In A. R. Metethan and R. A. Hudson (Eds.) Encyclopedia of linguistics information and control. London: Pergamon, 1969(a), Pp. 80-84.

Posner, M. I. Memory and thought: An introduction to cognitive psychology. New York: Scott-Foresman. In preparation.

Posner, M. I. On the relationship of letter names and superordinate categories. Quarterly J. of Psychology, 1970(b), 22, 279-287.

Posner, M. I. Perception. Yearbook of Science and Technology, New York: McGraw Hill, 1971(b).

Posner, M. I. The psycho-biology of attention and memory. In M. Gazzaniga and C. Blakemore (Eds.), Handbook of psycho-biology, 1972(d). In preparation.

Posner, M. I. Reduced attention and the performance of "automated" movements. J. of Motor Behavior, 1969(b), 1, 245-251.

Posner, M. I. & Boies, S. . Components of attention, Psychological Review, 1971, 7 391-408.

Posner, M. I., Boies, S. ., Eichelman, W. H., & Taylor, R. L. Retention of visual and me codes of single letters. J. of Experimental Psychology Monograph Supplement, 1969, 79, 4-16.

Posner, M. I. & Keele, S. W. Attention demands of movements. Proceedings of the XVIth International Congress of Applied Psychology. Amsterdam: Swets Zeinlinger, 1969.

Posner, M. I. & Keele, S. W. Retention of abstract ideas. J. of Experimental Psychology, 1970, 83, 304-308.

Posner, M. I. & Keele, S. W. Skill learning. In Handbook of research on teaching. American Research Association. In press.

Posner, M. I. & Klein, R. On the functions of consciousness. In S. Kornblum (Ed.) Attention and performance IV. New York: Academic, 1972. In press.

Posner, M. I., Klein, R., Buggie, S., & Summers, J. On the selection of signals. Memory and Cognition, 1973, 1, 2-12.

Posner, M. I., Lewis, J. L., & Conrad, C. Component processes in reading: A performance analysis. In J. Kavanaugh and I. Mattingly (Eds.) Language by ear and eye. Cambridge, Mass.: MIT Press, 1972. In press.

Posner, M. I. & Taylor, R. L. Subtractive method applied to separation of visual and name components of multi-letter arrays. Acta Psychologica, 1969, 30, 104-114.

Posner, M. I. & Warren, R. Traces, concepts and conscious constructions. In A. W. Melton and E. Martin (Eds.) Coding theory in learning and memory. New York: Holt, Rinehart & Winston, 1972.

Reicher, G. M. Perceptual recognition as a function of meaningfulness of stimulus material. J. of Experimental Psychology, 1969, 81, 275-280.

Reicher, G. M., Haller, R. W. & Aitken, A. G. Further investigations on the master's eye. Submitted to Perception & Psychophysics.

Reicher, G. M., Ligon, E. J. & Conrad, C. H. Interference in short-term memory. J. of Experimental Psychology, 1969, 80, 95-100.

Rogers, H. & Hyman R. Random notes and dancing dots. In preparation.

Rogers, M. Visual generation in the recognition of faces. M. A. Thesis, 1972.

Schaeffer, B. & Wallace, R. The comparison of word meanings. J. of Experimental Psychology, 1970 (a), 85, 144-152.

Schaeffer, B. & Wallace, R. Interdependence of rule-learning and attribute-learning. Perception & Motor Skills, 1968, 27, 239-246.

Schaeffer, B. & Wallace, R. Semantic interference: Obligatory or optional? J. of Experimental Psychology, 1970 (b), 86, 336-337.

Schaeffer, B. & Wallace, R. Semantic similarity and the comparison of word meanings. J. of Experimental Psychology, 1969, 82, 343-346.

Schwank, J. Design parameter for Oregon election ballots. M. A. Thesis, 1971.

Schwank, J. Menstrual cycle: Performance on various laboratory tasks. Unpub. paper.

Schwank, J. The role of the menstrual cycle on human female behavior. Unpub. paper.

Silveira, J. The role of incubation of problem solving. Ph. D. Dissertation, 1971.

Snyder, C. R. Familiarity and processes of visual search. M. A. Thesis, 1970.

Snyder, C. R. Individual differences in imagery and thought. Ph. D. Dissertation, 1972 (a).

Snyder, C. R. Selection, inspection and naming in a visual search. J. of Experimental Psychology, 1972 (b), 92, 428-431.

Stewart, M. R. Is the log law a special case of the power law? In preparation.

Stewart, M. R. Memory and absolute judgment. Ph. D. Dissertation, 1969.

Stewart, M. R. & Fagot, R. F. Further tests of a response bias model of bisection. In preparation.

Taylor, R. L. Comparison of short-term memory and visual sensory analysis as sources of information. J. of Experimental Psychology, 1969 (a), 81, 515-522.

Taylor, R. L. On recognition as a discrete event. American J. of Psychology, 1969 (b), 82 259-265.

Taylor, R. L. A study of the relative efficiency and interdependence of short-term memory and visual sensory analysis as sources of information. Ph. D. Dissertation, 1968.

Turnbull, E. Visual and name processes in a visual search task. M. A. Thesis, 1971.

Umilta, C. A., Frost, N., & Hyman, R. Interhemispheric effects on choice reaction times to one-, two-, and three-letter displays. J. of Experimental Psychology, 1972, 93, 198-204.

Umilta, C. Snyder, C. R., & Snyder, M. Repetition effect as a function of event uncertainty. J. of Experimental Psychology, 1972, 93, 320-326.

Wallace, R. S-R compatibility and the idea of a response code. J. of Experimental Psychology, 1971, 88, 354-360.

Wallace, R. S-R compatibility: Evidence concerning underlying processes. M. A. Thesis, 1970.

Warren, R. E. Short-term memory for simultaneous digits. M. A. Thesis, 1968.

Warren, R. E. Stimulus encoding and memory. Ph. D. Dissertation, 1970.

Warren, R. E. Stimulus encoding and memory. J. of Experimental Psychology, 1972, 94, 90-100.

Well, A. D. The influence of irrelevant information on speeded classification tasks. Ph. D. Dissertation, 1969.

Well, A. D. The influence of irrelevant information on speeded classification tasks. Perception & Psychophysics, 1971, 10, 79-84.

Wickelgren, W. A. Context-sensitive coding and serial versus parallel processing in speech. In J. H. Gilbert (Ed..), Speech production-speech perception. New York: Academic Press, In press (a).

Wickelgren, W. A. Phonetic coding and serial order. In E. C. Carterette and M. P. Friedman (Eds.), Handbook of perception: Language and speech, Vol. 7, New York: Academic Press, In Press (b).

Wickelgren, W. A. Strength-resistance theory of the dynamics of memory storage. In R. C. Atkinson, D. H. Krantz, R. D. Luce, & P. Suppes (Eds.), Contemporary developments in mathematical psychology. In preparation.

Wickelgren, W. A. & Berian, K. M. Dual trace theory and the consolidation of long-term memory. J. of Mathematical Psychology, 1971, 8, 404-417.

Wickelgren, W. A. & Norman, D. A. Invariance of forgetting rate with number of repetitions in verbal short-term recognition memory. Psychonomic Science, 1971, 22, 363-364.

## ARPA TALKS AND PAPERS


Buggie, S. Processing of sensory and name codes during the matching of disoriented letters. Meeting of the Western Psychol. Assoc., 1971.

Corrigan, B. Constant error in the perceptual extrapolation of straight lines. Meeting of the Western Psychol. Assoc., 1970.

Fagot, R. Psychological scaling. Psychological scaling. Symposium at Mathematical Psychology Meetings, La Jolla, Calif., 1972.

Frost, R. R. & Snyder, C. R. R. Stimulus localization and attention in a reaction time paradigm. Meeting of Western Psychol. Assoc., 1970.

Harrington, M. & Schaeffer, B. Priming semantic memory. Meeting of the Western Psychol. Assoc., 1971.

Hintzman, D. L. Effects of repetitions and input modality on memory. Stanford University, 1972.

Hintzman, D. L. Memory for repetitions and modality. Verbal Learning Conference, Lake Arrowhead, Calif., 1971.

Keele, S. W. Controlling U. S. population growth. Invited address at the Meeting of the Western Psychol. Assoc., 1971.

Keele, S. W. Psychology and population: What can be taught? Meeting of the Western Psychol. Assoc., 1970.

Lewis, J. L. Level of processing of unattended messages. Meeting of the Western Psychol. Assoc., 1968.

Lewis, J. L. Semantic processing with bisensory stimulation. Meeting of the Western Psychol. Assoc., 1971.

ARPA TALKS AND PAPERS

Lewis, J. L. & Osgood, G. W. Son of Zoro: Second generation multiprogramming system for psychological research. Spring Decus, 1971.

Posner, M. I. Abstraction and the process of recognition. Series of lectures, State University of New York, 1968.

Posner, M. I. Abstraction and the process of recognition. Birkbeck college, University of London, 1969. University College, London, 1969. University of Brussels, 1969. University of Paris, 1969.

Posner, M. I. Attention and the control of movement. Address of the Psychological Society, University of Cambridge, 1969. Hull University, 1969. Sheffield University, 1969. University of Brussels, Colloquium, 1969.

Posner, M. I. Attention and the control of motor movements. University of Brussels, 1969.

Posner, M. I. Attention demands of movements. International Congress of Applied Psychology, Symposium on Work and Fatigue, Amsterdam, 1968.

Posner, M. I. Attention and information processing. Colloquium, University of Minnesota, Minneapolis, 1970.

Posner, M. I. Attention and information processing. Invited address. Meeting of the Western Psychol. Assoc., 1970.

Posner, M. I. Cognition...Natural and artificial. Loyola Conference on Cognitive Psychology, 1972.

ARPA TALKS AND PAPERS

Posner, M. I. Components of attention. Stanford University, 1970. University of Waterloo, Queens University, Kingston, Ontario, 1970. University of Connecticut, Storrs, 1970. University of Utah, Salt Lake City, 1970.

Posner, M. I. Components of attention. University of British Columbia, 1971. Harvard University, 1971. Rockefeller University, 1971. University of California at San Diego, 1971. Colorado University, 1971. Washington University at St. Louis, 1971. University of California at Los Angeles, 1971.

Posner, M. I. Coordination of codes. Verbal Learning Conference, Lake Arrowhead, Calif., 1971.

Posner, M. I. Coordination of internal codes. Eighth Carnegie Conference of Cognitive Psychology. 1972.

Posner, M. I. Duscussion on hunting the CNV. Sumposium, Meeting of the Western Psychol. Assoc., 1970.

Posner, M. I. Does preparation require processing capacity? Applied Psychology Research Unit, Cambridge, 1969.

Posner, M. I. Human information processing. Short course in engineering psychology, University of Michigan, 1968.

Posner, M. I. Measurement of internal sensory-motor processes. Neuropsychology, Queen Square Hospital, London, 1969.

Posner, M. I. Motor control. Psychological Society, University of Dundee, Scotland, 1968.

Posner, M. I. Movement control. Emory University, Atlanta, Georgia, 1970.

ARPA TALKS AND PAPERS

Posner, M. I. Natural history of movement control. Invited address, 1st Canadian Symposium on Psychomotor Learning and Sports Psychology, Edmonton, 1969.

Posner, M. I. On the process of preparation. Paper presented to the Psychonomics Society, 1968.

Posner, M. I. On the relationship between letter names and superordinate categories. Experimental Psychology Society, London 1969.

Posner, M. I. Retention of visual and name codes of letters. University of Sussex, 1968. Applied Psychology Unit, Cambridge, 1968. Reading University, 1968. Durham University, 1969.

Posner, M. I. Selectivity in the processing of signals. Invited address. Meeting of the Midwestern Psychol. Assoc., 1972.

Posner, M. I. Selectivity in processing signals. University of Calif. at Los Angeles, 1971; University of Calif., 1971; University of Texas at Arlington, 1972; IBM, 1972; Yale University, 1972.

Posner, M. I. Separating levels of processing of visual information. Symposium on visual information processing, Mathematical Psychological Meetings, Ann Arbor, 1969.

Posner, M. I. Serial and parallel process in the nervous system. University of Aberdeen, Scotland, 1969.

Posner, M. I. Short term memory and human information processing. University of Technology, Loughdorough, 1969.

Posner, M. I. Studies of the process of recognition. Oxford University, 1969.

ARPA TALKS AND PAPERS


Posner, M. I. Subtractive method applied to separation of visual and name codes. Symposium honoring Donders, Eindhoven, The Netherlands, 1968.

Posner, M. I. Visual and name codes of single letters. Stanford University, 1968. Psycholinguistics Colloquium, University of Texas, 1968. Carnegie Mellon University, 1968. Pennsylvania State University, 1968.

Posner, M. I. Buggie, S. & Summers, J. Selection of Signlas. Psychonomics Society, 1971.

Posner, M. I. & Keele, S. W. Time and space as measures of mental operations. Invited address, American Psychol. Assoc., 1970. University of British Columbia, 1970.

Posner, M. I., & Klein, R. On the functions of consciousness. The 4th Meeting on Attention and Performance, Boulder, Colorado, 1971.

Posner, M. I., Lewis, J. L., & Conrad, C. Component processes in reading: A performance analysis. Invited address to the Conference on the relationship of speech to learning to read, Baltimore, 1971.

Posner, M. I., & Warren, R. E. Traces, concepts and conscious constructions. The Conference on Coding Processes in Memory, Woods Hole, Massachusetts, 1971.

Posner, M. I., & Wilkinson, R. On the process of preparation. Psychonomics Society, 1969, St. Louis, Missouri.

Rogers, H. W., & Hyman, R. Random notes and dancing dots. Meeting of the Western Psychol. Assoc., 1972.

ARPA TALKS AND PAPERS

Schaeffer, B., & Wallace, R. The role of semantic transformation in semantic interference. Meeting of the Western Psychol. Assoc., 1970.

Schaeffer, B. & Wallace, R. Semantic interference: Obligatory or optional? Meeting of the Western Psychol. Assoc., 1970.

Silveira, J. Incubation in problem solving. Meeting of the Western Psychol. Assoc., 1972.

Snyder, C. R. Selection, inspection, and naming in visual search. Meeting of the Western Psychol. Assoc., 1971.

Stewart, M. R. Memory and absolute judgment: Tests of a bisection model. University of Washington, 1969; Northern Illinois University, 1969.

Wickelgren, W. Dunamics of memory. Stanford University, 1969; University of Calif. at Los Angeles, 1970; University of Calif. at San Diego, 1970.

Wickelgren, W. Trace resistance and the decay of long-term memory. Oklahoma State University, 1971; Mathematical Psychology Meetings, Princeton, 1971; Invited Address, Division 3, Meeting of the American Psychol. Assoc., 1971; University of Calif. at Berkeley, 1971; Conference on Alcoholic Blackout, St. Thomas, Virgin Islands, 1972.